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EXPERT TESTIMONY AND THE MICROSCOPIC EXAMINATION OF BLOOD.

(*Continued from Sept. No., ante, p.* 540.)

THE question is not whether under all circumstances blood corpuscles retain their size, for this must be answered at once in the negative, but whether in any particular case under examination, they meet this requirement; nor indeed is this last by any means absolutely necessary; for suppose the question to be between hog's blood and human blood, and the human corpuscles could be shown to have shrunken from the $\frac{1}{3100}$ of an inch to the $\frac{1}{3200}$ of an inch, still the distinction would be sufficiently wide for the purpose of recognition. It will be seen, that for the mere answer to the question at the head of this article (when put in its proper form), Can the blood of human beings be distinguished from that of the other red-blooded animals, but just two words would be necessary, viz., "yes" and "no," and the discussion might be stopped at this point; but so much is being said upon the subject, and so frequently is it brought into the courts, that it becomes of paramount importance to fully understand it in all its bearings.

Recognising the fact that every case should be tried upon its own merits alone, I proceed to mention some of the various forms under which the question may present itself, and to examine these in detail.

First, a spot being ascertained or admitted to be blood, can we say positively it is human blood, and not the blood of some other animal, whose corpuscles are near in size to those of man—those of the dog, for instance? The answer of course must be in the negative. We could not swear positively as to the fact. But then, would the investigation in every case of this kind, confining our answer to the question of measurement alone, be of no value whatever as evidence?

Suppose we admit, for the sake of this investigation, that Dr. Woodward's highest average, as given in the Hayden trial, that of puppies' blood, 50 corpuscles averaging the $\frac{1}{3067}$ of an inch, and the blood in the case alleged to be dog's blood, measuring no more than this, would even then the probabilities if its being human blood, be of no value as evidence? Suppose this to have been the result in my own experience, it would be an exceptional case out of nearly or quite two hundred dogs, including twenty-five puppies, whose blood I have measured.

I give with this paper synopses of tables of the measurement of blood corpuscles, from fifty (50) adult human beings, and three (3) infants, and that of fifty (50) dogs, including thirteen (13) puppies. The highest average of dog's corpuscles is from the blood of a puppy, giving 310 millionths, *i. e.* the $\frac{1}{3220}$ of an inch. The largest corpuscles in one of these tables measure 392 millionths, *i. e.*, the $\frac{1}{2549}$ of an inch; the average of this particular table being 318 millionths, equal to $\frac{1}{3137}$ of an inch. It will be seen by this that the presence of extra large corpuscles by no means necessitates that the average shall be larger than those where such extreme sizes are not present. It will be remembered that each number or row of figures in a synopsis, represents the measurement of corpuscles as arranged in tables as seen in Plate 1, save that the first or general average tables are made up of 36 corpuscles each, and the selected large-sized corpuscles of 25 each. The extremes, of course, represent the measurement of single corpuscles. The whole number of corpuscles in these two groups of tables, thus drawn and measured, amount to over 6400. Special descriptions are attached to each synopsis of tables.

Up to the time of my last paper, these measurements and comparisons of blood corpuscles had been made between those of adult individuals in every case. Since then it occurred to me that the prenatal size of the corpuscles might remain for a greater or less

time during the period of infancy. In the case of five puppies of three weeks of age, I found the corpuscles of four to be of the usual adult size, while those of the fifth were as large as the largest in my table. And also, in case of a litter of pigs, twelve hours old, I found the average to be the $\frac{1}{3732}$ of an inch. The largest corpuscle measuring 296 millionths, *i. e.*, the $\frac{1}{3374}$ of an inch. I made two tables of 49 corpuscles each, of the blood of one of these pigs. The average of one table gives 2663 ten-millionths of an inch; the other, 2677 ten-millionths of an inch. Variation 14 ten-millionths of an inch. And the same fact I found to exist, as regards the corpuscles of the human infant. It will be seen that the average here goes as high as 350 millionths, *i. e.*, the $\frac{1}{2854}$ of an inch.

Suppose in a given case we should find blood corpuscles averaging as large as this, would such a fact be of no value as evidence, either upon the ground that these corpuscles averaged larger than any recorded or than any probable average of adult dog's blood? And, further, would not the finding of a sufficient number of corpuscles to give an average of, say the $\frac{1}{3000}$ of a inch or the $\frac{1}{3200}$ of an inch, even be of some value as evidence as between human blood and dog's blood, it being shown to be exceptionally large as it regards this last? I do not say how large a number of corpuscles should be measured in a given case in order to warrant us in relying upon the mathematical result as settling the questions of average.

In this same Hayden trial, Dr. Woodward says that he could not give the general average of a dog "by counting 10,000 corpuscles, or that of five dogs by forty years' labor." That is, according to Dr. Woodward, there is no possibility of getting the average measurement of a large number of objects of varying sizes. Perhaps in a strict mathematical sense this may be correct, but practically speaking, that is, as a basis for calculation and practical application in a given case, nothing could be more incorrect.

Thus it will be seen by my tables giving the average measurement of 1176 corpuscles, measured both ways, in tables of 49 corpuscles each (synopsis of tables No. 3), that the greatest difference between any two tables is 6 millionths of an inch; between two united, constituting tables of 98 corpuscles each, greatest difference five millionths of an inch; between four tables united, constituting tables of 196 corpuscles each, greatest difference 22 ten-millionths of an inch; while the difference between the first

half of the 24 tables composed of 588 corpuscles and the last is but 4 ten-millionths of an inch. This is approaching very near to the absolute average of the slide. It seems to me a self-evident proposition without the proof of measurement that blood corpuscles, taken as they come, over a sufficiently wide extent of field, measured in the centre of the field-glass, with no variation in the length of the tube, must give, as is shown by my table, an almost absolute average.

Mr. S. W. Burnham, the astronomer, allows me to refer to him as endorsing this proposition.

Babbage says there is nothing more uncertain than the duration of individual life, while nothing is more certain than the duration of life as applied to a multitude of individuals. It would seem that this might apply with equal force as to the average size of individuals or their blood corpuscles.

As it regards the question of the probability of arriving at a general average of the blood corpuscles of large numbers of individuals, it must rest, of course, upon the solution of the question of that of single individuals already discussed. As a legal question it is of importance as showing in a given case that the blood in question comes within the bounds of human blood, and could not therefore be that of an animal whose highest average is much below that of human blood.

Dr. Woodward says, page 8, of printed report, "I have never twice been able to get the same average from fifty or one hundred corpuscles of human blood or dog's blood." He says, page 59, in the same connection, in answer to the question of counsel as to "how long it would take to find the average of dog's blood in his recent experiments?" *Ans.* "It could not be done. Forty years would not do it. I mean it solemnly. I mean to say I had the blood from five dogs—every one on a different slide. If I made an average from one slide, and then from another, having plumped down anywhere I pleased, and then doing it over again, I never would have got twice the same figure."

If this is correctly reported then the statement amounts simply to a guess of what "he would have got," if he had "done the thing over again." If it is based upon the experience of "plumping down anywhere I please," by which is meant I suppose selecting a particular spot on the slide, this statement will be confirmed by every experienced observer, as frequently blood corpuscles will

group themselves so as to average a considerable difference in size in different groups. Especially is this the case when on some parts of the slide crenated corpuscles are met with. But even here just as fair averages may be obtained as it regards a single slide, if it be moved, say horizontally the distance the stage allows, and those corpuscles only are taken which pass across the centre, and provided always they are measured in two directions. I never omit this double measurement in any case, as it is impossible for most, if not all, persons to detect a slight degree of variation from the circular form, and this is sometimes mostly in one direction in blood corpuscles, perhaps owing to the manner in which the blood is applied to the slide or object on which it is received. It will be seen by my tables that I frequently get the same measurement from the same number of corpuscles from a single slide. The drawing and arranging of all the corpuscles before any measurement is made, as described in a former paper, precludes all possible prevision to this end. That is, I cannot know what will be the measure of any given table of any number of corpuscles more or less until the whole have been fixed in the form of a drawing, which drawing is preserved and remains subject at all times to examination. As it regards the series of tables given in this paper representing the measurement of 7276 corpuscles, I have all the drawings as described and represented, both in this and former papers. And in the cases in which I have testified in court I have these drawings, as well as my printed testimony to refer to.

As a further illustration of the accuracy with which blood corpuscles can be measured by my method, I refer to Plate 2. This was drawn with the camera lucida, as is the fact in all these cases, and has been fully described in my former papers. It will be seen that the same eight corpuscles were used in each case, and that they have been measured only in the direction of the rows, as this was sufficient for the purpose had in view. All the drawings were made with a one-twelfth object glass and Tolle's amplifier. The (B) eye-piece was used in making the first four rows; the (C) in making the last.

The greatest care is taken in regard to the points of contact of the corpuscles. The likeness of the different drawings to the originals require less attention, as this is not essential to the test. They have been somewhat carefully preserved, however. The measurement of the rows in inches is as follows:

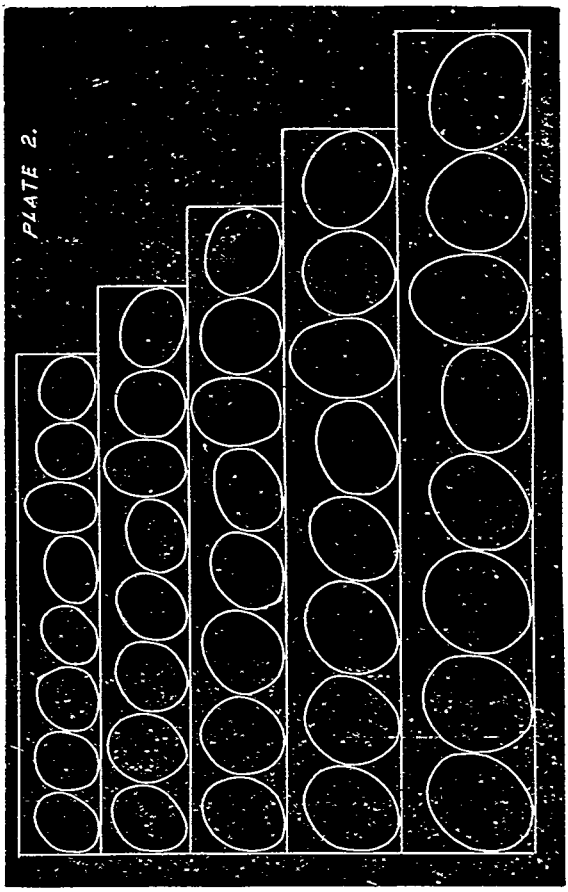

Plate 2.

Row No. 1 (B) eye-piece, draw-tube pushed home, magnifying power 1124 diameters, average 1-3382 of an inch.
Row No. 2 (B) eye-piece, draw-tube out one inch, magnifying power 1274 diameters, average 1-3383 of an inch.
Row No. 3 (B) eye-piece, draw-tube, out two inches, magnifying power 1448 diameters, average 1-3382 of an inch.
Row No. 4 (B) eye-piece, draw-tube out three inches, magnifying power 1620 diameters, average 1-3383 of an inch.
Row No. 5 (C) eye-piece, draw-tube pushed home, magnifying power 1840 diameters, average 1-3388 of an inch.

No. 1, 2.66; No. 2, 3.02; No. 3, 3.42; No. 4, 3.83; No. 5, 4.35. By making the proportion between the first measurement in inches 2.66, and the first magnifying power 1124, and the measurement of the second row 3.02, we get magnifying power 1275 for the second, 1455 for the third; 1618 for the fourth, and 1838 for the fifth. The averages expressed in ten-millionths of an inch as produced by actual measurement, are as follows:

No. 1, 2956; No. 2, 2954; No. 3, 2954; No. 4, 2956; No. 5, 2951.

The results which come from the measurement by means of the micrometer scale, as corrected by calculation, are:

No. 2, 2962; No. 3, 2965; No. 4, 2958; No. 5. 2951. Greatest difference fourteen ten-millionths of an inch. I claim for my method of measurement in my own hands a much greater degree of accuracy than has thus far been published, as having been reached by others by different methods. On p. 26 of report of Hayden trial, Dr. Woodward says, "I do not suppose that any man of science ever pretended, that there was an absolute correct measurement under the microscope; we only hope to approximate to the truth, and sometimes we can approximate to it very closely." Again, on same page, he says, "in measuring fine lines (spaces between the lines), microscopists would not probably differ among each other more than three or four millionths of an inch." On p. 65, he says, "There is no certainty about any measurement in the microscope." On p. 22, he remarks in connection with his description of the various methods of measurement used by microscopists, "very accurate results indeed can be obtained by every one of these methods." On p. 61, he says, "I have made decided errors as to the average sizes, but not as to size of individual corpuscles."

On p. 10, he says, "I criticise my own figures, not because any single measurement was incorrect. I believe now that each corpuscle was measured correctly as closely as the unit of measurement which was used could have been applied by any living person."

The discrepancies existing between these last quotations are so marked as scarcely to require comment. How any one could say in one place, "There is no certainty about any measurement in the microscope," and in another, a few pages back, could declare that very accurate results indeed can be obtained, not by one method alone, but by several, thus each serving to confirm the other, is beyond my comprehension.

I do not mean to be in the least degree personal in this paper, but one cannot help thinking, notwithstanding the gravity of the subject, of a certain philosophical gentleman who was elected a member of seventeen foreign learned societies on account of a wonderful antiquarian discovery he chanced to make.

However important we deem this question of microscopic measurement, in a scientific point of view, still its settlement to the

utmost limit of nicety, is of but little consequence as it regards legal cases. The variation of a few millionths of an inch would hardly be taken into account as of any value in a given case.

Provided, in making comparative measurements of blood corpuscles, we keep the tube of the instrument of the same length in every examination, and use, as I think we should do in such cases, object-glasses without collar adjustment, and bring the corpuscles to the centre of the field, measuring them in two directions, I hardly think we need to fall into any error of sufficient importance to affect the result one way or the other. The specimens in question being subject to the same conditions of examination, could not fail to be fairly compared with each other, and this is all that is required in any case. Of course such examination, to be of any value, must be in the hands of one who has made the subject a special study for a considerable period of time.

On p. 5, of this report, Dr. Woodward says: "Now I should say that the largest and smallest blood corpuscles are not to be found in every drop, either of human or dog's blood, nor even in the blood of every animal." Leaving entirely out of view this remarkable piece of testimony of the scientific witness as to what would be the fact in regard to the "blood of every animal," what shall we say of the statement in regard to the contents of a single drop of blood? On p. 12 the doctor tells us the fact that there are 5,000,000 corpuscles in a cubic millimeter of blood, a millimeter being of the "size of the head of a very small pin." The dot over the *i* in the text measures the $\frac{1}{50}$ of an inch in diameter; this is one-half the diameter of the cubic millimeter. This by calculation would give at least 100,000,000 corpuscles to a single drop. If guessing is to be received as testimony, one would certainly think that a directly opposite statement to this would be the one to be allowed in the case, and that we should be pretty likely to get all sizes of the blood corpuscles of a single individual in this vast number. But of course this is not evidence at all; it is not scientific guessing, for there can be no such thing. It is the guessing of a professor of science, and is just such testimony as warrants the legal profession in saying that they can prove anything by professional experts.

In this trial, Dr. W. attributes the wide differences in the averages as given by the different observers to the nature of the subject as expressed above. In the London Microscopic Journal of February 1878, he says, "doubtless all the measurements were

somewhat vitiated like others of the same date, by the failure to allow for the variations in magnifying power produced by turning the screw collar." Would it not, in the present case, be much more reasonable to refer the fact to some such cause than the one selected? In a communication to the American Monthly Microscopical Journal, vol. 1, March 1880, he tells us that the average usually accepted in Germany, that of Welker [Zeitschr. fur Rat. Med., Bd. xx, 1863, s. 236] is 774 micromillimeters (*i. e.*, 394 millionths or $\frac{1}{32\frac{1}{89}}$ of an inch). This is very near my own average deduced from the measurement of the blood corpuscles of more than two hundred individuals, of several different nationalities; *e. g.*, in my published paper in 1877, $\frac{1}{32\frac{1}{61}}$ of an inch, in this paper, excluding infants' blood, $\frac{1}{32\frac{1}{47}}$ of an inch, and all these measurements have been made with a dry object glass (without screw collar adjustment), made to my order expressly for this work. Moreover, since drawing all the corpuscles from the centre of the field, I have reduced the average from about the $\frac{1}{32\frac{1}{00}}$ of an inch to the present figure. This, of course, will be easily understood as depending upon the laws of optics. May not the high averages of Pellouse & Frémy, $\frac{1}{102}$ of a millimeter, *i. e.*, 328 millionths, or $\frac{1}{30\frac{1}{48}}$ of an inch, depend upon their having been made up from the measurement of corpuscles of both adult and infant blood? This, of course, as in the case of dogs, would produce very varying averages, as the relative numbers of individuals of the different ages might vary.

The average of the 53 tables of adult and infants' blood united, is 3102 ten millionths, $\frac{1}{32\frac{1}{26}}$ of an inch, while the adult tables alone average 3079 ten millionths, $\frac{1}{32\frac{1}{47}}$ of an inch. How far towards adult age the prenatal size of the blood corpuscles may be carried, remains, I think, a subject for future inquiry. This condition certainly is, as I have proved, quite indefinite in the case of dogs, and it is reasonable to suppose that the same fact may exist in regard to human individuals.

Here, then, may be one of the sources of the discrepancies of the authorities on this subject. Another I have pointed out as due to measuring the corpuscles outside the centre of the field. How far diseases may cause variations in the size of the corpuscles remains to be settled. They have, as I have proved, a considerable influence in this direction. Now here are certainly facts enough to account for the discrepancies alluded to, without resorting to the guess that among a hundred million corpuscles from a single indi-

vidual, there could not be found all the various sizes contained in the blood of said individual.

On p. 182, to return to the Central Law Journal, the editor says: "The conclusion to be drawn from the testimony of all these experts is that by the appearance and measurement of the blood corpuscles with the aid of the microscope, blood can be distinguished from all other substances," &c. On p. 188, Dr. Laws says, "Dr. J. G. Richardson * * has formulated the opinion that with our present improved microscopes we can give a positive opinion as to the difference between human blood and that of *ordinary* domestic animals." And quoting from Beck's Medical Jurisprudence, 1863, vol. 2, p. 147, he gives the following: "Little difficulty can now be experienced in finding in any large community more than one physician who could with great certainty identify blood corpuscles under the microscope." "Such statements are believed to be misleading," says the professor: "the identification of a blood corpuscle falls very far short of the differentiation of the blood corpuscle of one animal from that of another," &c.

Now if this odd jumble of extracts were strictly true or correctly made, it would be difficult to see what bearing they have upon the question. But so far from being correct, that from Dr. Richardson carries with it an entire perversion of the truth.

On p. 288 of his Medical Microscopy, Philadelphia 1871, he says, "Usually, as a rule it is only required, that a positive diagnosis shall be made between" not '*the ordinary domestic animals*,' as quoted above, but "those commonly slaughtered for food, such as the ox, the sheep, or the pig, and of birds," &c., and in the London Microscopical Journal 1878, p. 215, Dr. Richardson says: "There is at present, as far as I am aware, no method known to science for discriminating the dried blood of a human being from that of (those domestic animals) the dog, rabbit," &c.

"Such statements are believed to be misleading," says the Professor. What statements? His own false one, in regard to Dr. Richardson, or his equally false inference in regard to Beck, who nowhere even intimates the idea thus attributed to him, that he or anyone else, to his knowledge, ever claimed to be able to differentiate the "blood of one animal from that of another?" If he means that the statement of Beck in regard to identifying blood corpuscles, *per se*, is incorrect, *misleading*, then he completely stultifies the conclusions stated above "that by the appearance and measurement

of the blood corpuscles, with the aid of the microscope, blood can be distinguished from all other substances." This we are told is the conclusion drawn from the testimony of all these experts, among whom Prof. Laws occupies no minor position.

And thus one might go over this whole paper, finding in almost every sentence, such an odd jumble of false statements and misapplied facts as it would seem almost impossible to crowd into so small a space. Thus, Sorby is quoted as saying that he does "not at present, see any probability of deciding by the spectra from what animal blood may have come in a given case." Suppose we should add that by the haemin-crystal test, or by the guaicum test, we do not see any way to accomplish such results. No one has ever claimed this for these tests; they simply show the presence of blood and that is all. What then in the name of law and logic have they to do with the question?

When we consider that such a paper as this is claimed as authority, upon a subject of grave importance, we can scarcely help comparing it to that immortal treatise upon Chinese metaphysics which we are told was compiled from the Encyclopædia Britannica, its author reading under the letter C for Chinese, and the letter M for metaphysics, and then uniting the results of his lucubrations. It is "based upon false statements," inasmuch as that neither Dr. Treadwell, nor any other expert, as I believe, ever in any case claimed to be able to *identify* human blood or the blood of any animal whatever.

The question is not whether "human blood and animal blood can be distinguished," but whether human blood can be distinguished from that of other animals? If it should read *all* other red-blooded animals, the answer must be in the negative; but if it read "from a very large proportion of these animals," in many cases the answer would be as certainly in the affirmative.

The paper in the Central Law Journal cannot, in any sense, claim to have settled the question of the "identification of human blood." No one pretends this can be done, but if this were the case, not a single one of the authorities quoted out of which the paper has been compiled, says anything at all upon this question. Taylor uses the word "distinguishing." Dr. Woodward is quoted as using the word "distinguish." Dalton uses the word "distinguish" and Beck "differentiate," which, of course, means the same thing, and the German authority quoted, also uses the word "distinguished." What

then does the paper mean by thus summing up, as if the question asked, was limited by the word "identify?" Neither is the question (understood in its true meaning) answered at all, except by Dalton, as quoted before, who in his edition 1875, published one year after Dr. Richardson's paper, says, "we can often distinguish the blood of an inferior animal from that of a human subject."

All the other authorities quoted in the negative, were, as we have seen, at the time when they made their statements, incapacitated from coming to any other conclusion, from the want of instruments of sufficient power with which to investigate the subject.

It may be thought, perhaps, that the writer has gone to unnecessary trouble, in answering this paper at all, and he would say by way of apology, that he was asked to do so by professional gentlemen, who deem the subject to be one of much importance, and who are aware that it is just such crude opinions as these, that are received in the courts as testimony; for it will be remembered that the whole is compiled from the utterances of those liable to be called as witnesses in such cases. And further, not long since he was consulted by a prosecuting officer in this very state of Missouri, in a case of most brutal murder, in which the prisoner claimed that he had hog's blood on his clothes, in which the examination was prevented by men in prominent positions, who knew as much about the matter as those consulted in the present case, that is, "not so much from personal experiments as from examinations of the authorities," &c. Is it not also a curious fact, that in this paper we are told "that the defendant says it is the blood of an animal," which is seen on his clothes, without our ever being informed from what animal it was alleged to have come? Had he claimed it to be hen's blood, as in a case reported by Dr. Richardson, surely there would not have been a professor of them all who could not have distinguished it from human blood, as was done in that case.

The whole question may be, I think, summed up as follows:

1. Human and other mammalian blood, the corpuscles of which are circular, can be distinguished by the criterion of form from that of all other red-blooded animals, with the exception of that of the monotremata (ornithorhynchus and echidna), which, according to Gulliver, have circular corpuscles. The camel family, which belong to the class mammalia, have oval corpuscles, as do all those not belonging to the mammalia, with the exception noted above.

2. Human blood can be distinguished from that of other red-

blooded animals having circular corpuscles, in every case of individual comparison, where the average size of the corpuscles is greater than those of the animal with which it is compared, or where the largest corpuscles are larger than the largest of those of the animal with which they are being compared.

3. Human blood may be distinguished in a given case from that of an animal (the dog for example), in which the averages of the corpuscles, and the size of single corpuscles in individual cases, are equal to or exceed that of the average of human blood.

4. Under the same conditions of actual individual comparison, the blood of two individuals of the same species may be distinguished from each other.

5. Blood may be distinguished by the opposite conditions of disease and health, as between individuals of the same species, or between a human being and a lower animal.

This, as I believe, covers the whole ground, and is, I think, all that is claimed by any one who has made any extended investigation upon the subject.

The case of Rubenstein, who murdered his cousin in New York some years since, illustrates the first proposition. The defence set up the claim that the blood on his clothes was hen's blood. This was disproved by Professor Eaton, who found that the blood was mammalian blood. And what is of further interest as showing the value of microscopic examinations, outside of the blood question, he found pieces of corn husks mixed with the blood, and particles of earth, which could be identified as the same kind as that of the cornfield in which the murder was committed. And I may here remark that in every case of the kind in which I have myself been called to act, I could have arrived at a correct answer to the questions submitted to me had I not been able to make out the class of animal to which the blood belonged. I mean, that after settling the fact of the presence of blood, and, indeed, in some cases, had not this been settled at all, the other facts discovered in the course of the examination would have enabled me to arrive at a just conclusion. This will be more fully illustrated hereafter.

In a murder case in a neighboring state, the accused, who was accustomed to do butchering for the farmers and others in the vicinity, claimed that the blood on his clothes was that of a hog he had killed that day. Now, hog's blood corpuscles, in accordance with my own repeated examinations, average 236 millionths, *i. e.*, the $\frac{1}{4235}$ of an inch, according to Gulliver the $\frac{1}{4230}$ of an inch.

Blood corpuscles were found on the clothes and knife of the accused, averaging about 312 millionths, or the $\frac{1}{3200}$ of an inch, with large corpuscles reaching as high as 387 millionths of an inch. It will be seen at once here, I think, that the statement of the criminal that the blood on his clothes was hog's blood, was demonstrated to be a falsehood. Suppose he had resorted to the trick of putting hog's blood on the garments already smeared with human blood, here the large corpuscles would have betrayed him.

Had it been claimed in this case that the blood of a very young pig was the source of the corpuscles in question, still the distinction would have been wide enough for us to arrive at a just conclusion in the premises.

In the London Microscopical Journal, 1871, page 215, Dr. Richardson gives the following account of a case in which he was engaged. He says: "After my testimony was delivered in the Lambee trial at Franklin, Venango county, Pennsylvania, the prisoner's 'keen, sharp-witted lawyer,' brought two female witnesses into court, who testified that on a certain occasion, about the time of the murder, they were engaged in clipping the ears of a terrier dog, which, after one ear was clipped, got loose and sprinkled the blood on the defendant's boots, which were standing in the corner of the room. Further, to substantiate this tale, a dog, with one ear clipped, was exhibited to the jury, and sworn to as the very one from whence the blood was shed." Previous to this, however, the doctor had examined some blood spots on the pantaloons, and found them to be human blood, in contradistinction to pheasant's blood, as was first explained by the accused. As the pantaloons were not in the boots at the time when they were said to be sprinkled, of course this defence failed in both these points. Suppose, in this case, both the pheasant's blood and the circumstance of the pantaloons having been separate from the boots at the time of the alleged blood-sprinkling, had been absent? Then resort might have been had to the comparison of the blood of the living dog present, and had this blood measured, say in the proportions of the first two numbers in my tables, *e. g.*, 2969 and 3183 ten-millionths of an inch human. 2855 and 2737 ten-millionths dog's blood, there would not seem to have been much difficulty in coming to a conclusion. This conclusion, as will be seen by the tables, might have been still further confirmed by comparing the larger averages and the largest corpuscles with each other.

In the Wisconsin murder case, the *State* v. *Knoll*, in which the writer was engaged, the blood found on the planks in the barn was claimed to be the blood of pigs, cattle and sheep slaughtered there. On some of these planks blood corpuscles were found measuring as high as 370 millionths of an inch, which, of course, precluded the idea of their belonging to the animals alluded to. For some reason, in this case, which did not seem quite clear to the writer, the defendant's lawyers brought into court the blood of a dog, with an expert, who testified that dog's blood could not be told from human blood. Now, the largest corpuscle found in this blood measured 335 millionths of inch, while, as I mentioned above, I found a number in the blood from the planks, measuring 370 millionths of an inch. This, expressed in vulgar fractions, is 370 millionths $\frac{1}{2700}$ and 331 $\frac{1}{2950}$ of an inch. The average of the corpuscles also differed as widely. Thus, it will be seen in this case, had the question been between this dog's blood and the man's blood, the answer would have been obvious.

I mention, in passing, that I found, upon examination, perfectly formed and recognisable blood corpuscles in the heart of the murdered man after he had been buried seven weeks.

In further illustration of what I have said of the frequent instances in murder cases, in which the identification of blood corpuscles becomes of minor importance, I proceed to give some additional facts in the case last quoted:

It became important in one stage of the case, in order to furnish a missing link in the testimony, to connect the body of the murdered man with a wheel-barrow on which it was alleged it was transported some distance after death. I failed to identify corpuscles in the dried blood, which was found in the cracks and joints of the barrow, but in the course of the search for these bodies, I found a few short, coarse black hairs, which had been recently cut, as was evident from the squareness and sharpness of the cut ends. These hairs had been forcibly pulled from the head, as was shown by the bulbs adhering to them. They were compared with those on the head of the dead man, whose body had been exhumed as stated above, and found to be alike in size, color, &c. In addition to the hairs, there were found in the dried blood, cotton and wool fibres of various colors, precisely like those which constituted the mixed cotton and woollen shirt found on the body. I further discovered in the blood on the shirt and that from the barrow, corn and wheat-

starch, which was also met with in the manger where the young man had been accustomed to feed horses and cattle.

Here the identification of blood corpuscles as human, if it could have been done, would have added but little to the weight of testimony on this point, as they might have got on the barrow from an accidental wound, bleeding from the nose or other organ. This was quite likely to be the fact, as the barrow was in constant use about the stable and slaughter-house.

In illustration of the statement, that the blood of individuals of the same species can, in some instances, be distinguished from each other, I give a case in which this question is involved, where I was able to solve the problem. It is, so far as I know, the first and only case of the kind, in which the question has been presented in the courts. The case was tried at Canton, Ohio, December 1876.

A man had been killed by a bullet through the head, shot from a pistol in the hand of his wife. The charge was that of wilful murder, resting upon the alleged statement that he was shot while lying asleep in bed. The woman had two razor cuts in her throat, and was also wounded by a pistol shot in her side. She stated that her husband had attempted to murder her, and in this attempt had inflicted these wounds, and that in the scuffle she had snatched the pistol from his hand and had shot him through the head, as above stated. His body was found lying at the farther side of the room from the bed, where, as she said, he fell upon being shot. In the charge it was also alleged that her wounds were self-inflicted. The question presented to me for solution in the first place, was as to which of the two parties the blood on the sheet belonged. If to the wife, then she was innocent of the crime charged, if to the husband, then she was guilty. Preliminary to the examination of the blood spots themselves, I took the blood from the arm of the accused, and constructed tables for measurement of the corpuscles as described in my drawings. Next, search was made in the blood from the spots on the sheets, and the corpuscles found were arranged in similar tables. The last step in this part of the process was to make a similar examination of the blood on the carpet where the head of the dead man lay when he was found, and also of the blood spots on the sheets on which the post-mortem was made. A number of corpuscles were found here also, which were arranged in the tables as above. Upon measuring the first and second tables, those from the arm and those from the sheet from the bed, the corpuscles

were found to average very close to each other, while between these and those in the other tables which of course came from the man, there was quite a measurable difference, the first measuring the $\frac{1}{3340}$ of an inch, the other the $\frac{1}{3080}$ of an inch.

The conclusions arrived at from the results of the measurement, were confirmed by the substances found in the blood on the sheet where the woman's head lay, as she testified, and which, therefore, must have come from the wounds in her throat. I found in this blood, fine red-colored wool fibres, from a worsted scarf and blue silk fibres from ribbon, and also a single hair of the color and appearance of her own hair, as seen under the microscope. Where the man's head lay on the carpet, I found with the blood, spicules of the skull-bone, brain matter, and pieces of beard apparently of twelve hours' growth. It was proved on the trial, that for some reason, he had been shaved the night of the killing, as also in the morning of the same day, which circumstance, of course, gave time for the growth of the beard as found under the microscope. I have since tested this matter of the growth of the beard in persons that are in the habit of shaving and find it to be pretty uniform. At least, it is quite easy to distinguish beard of twelve, twenty-four and forty-eight hours growth.

None of the substances found on the carpet were met with on the sheet, where, as alleged by the prosecution, the man's head lay at the time of his death, and where it must have been, if the charge of murder were in any manner to be sustained.

Here it will be seen that, although the question, as put to the expert, was based upon the examination of the blood corpuscles alone, sufficient evidence was discovered during that examination, to have warranted a conclusion sustaining the woman's statement of the facts in the case. This, as I have mentioned before, has been the fact thus far in every case of the kind I have been called upon to investigate.

R. U. PIPER.

Chicago, June, 1880.

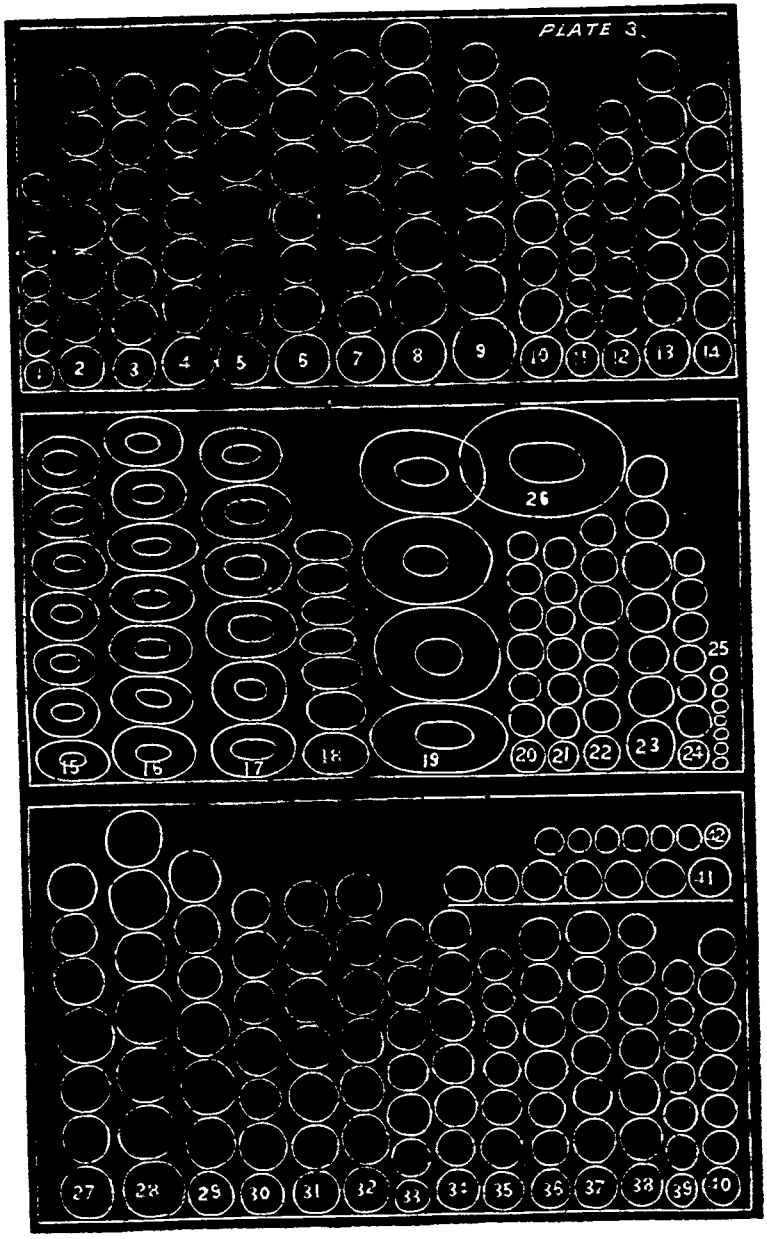
PLATE 3.
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Plate 3. Blood corpuscles of forty-two different species of animals, drawn to a scale of 1620 diameters, reduced in the engraving. Of course the measurement of so few corpuscles in each case would not be sufficient for the purpose of getting a general average. They will serve, however, to give a pretty good idea of the variation in size and form of the blood corpuscles of the animals from which they were taken. They were all drawn from actual specimens.

No. 1	Ibex,	No. 22	Harte Beest,
2	Grey Rat,	23	Yak,
3	Mouse,	24	Horse Antelope,
4	Wart Hog,	25	Musk Deer,
5	Sea Cow,	26	Frog,
6	Hippopotamus,	27	Whale,
7	Rhinocerous,	28	Elephant,
8	China Bear,	29	Human,
9	Hyena,	30	Dog,
10	Brazil Tiger,	31	Russian White Wolf,
11	Small Antelope,	32	Domestic Rabbit,
12	White Deer,	33	Ox,
13	Eland,	34	Sacred Ox,
14	Nil Gau,	35	Horse,
15	Perch,	36	Mule,
16	Hen,	37	Zebra,
17	Tame Pigeon,	38	Pig,
18	Camel,	39	Sheep,
19	Snake,	40	Cat,
20	Cow Antelope,	41	Sable Anteiope,
21	Gnu,	42	Goat.

Synopsis (No. 1). Human blood.

The corpuscles, the measurement of which is shown in this synopsis of tables, have been drawn as they passed under the centre of the object-glass. Upon examining the first two columns of figures, which give the measure of the rows in the tables, it will be seen that the variation, in this respect in the two directions, is sufficient, in many cases, to constitute an essential difference in the result. Take No. 18, for instance, here the rows measured both ways—in one direction give the 1-3362 of an inch, in the other, 1-3206 of an inch.

There are two sets of tables represented here—50 of 36 corpuscles each, and 50 of 25 (largest selected) each. The average measurement of the first is, the 3079 ten millionths = 1-3247 of an inch. In my published tables, I give 3062 ten-millionths = 1-3265 of an inch. In this paper is given 3 tables of infant's blood. They average much higher than those of the adult, *i. e.*, 3500 millionths = 1-2857 of an inch. This is also true of the blood of puppies. Heretofore conclusions in in this direction have been based upon the comparison of the blood of adult dogs with those of man. The only reliable conclusion in a given case must be based upon the actual comparison of the blood belonging to the individuals in question.

Synopsis (No. 1) of measurement of human blood corpuscles, magnified 1620 diameters.

Number.	Measure in inches of (50) human blood tables of (30) corpuscles each—measured in two directions.		Average in ten millionths of an inch.	Average in vulgar fractions.	Measure in inches of (50) tables of largest selected corpuscles (25) each—measured in two directions.		Average of large selected corpuscles.	Measurement of largest corpuscles.	Smallest corpuscles.
1	17.70	17 00	2969	1-3402	13.70	14.00	1-2924	1-2883	.....
2	18.30	18.85	3183	1 3143	13.35	13.65	1-3000	1-2940	.....
3	18.40	18.60	3109	1-3216	14.70	14.90	1-2782	1-2658	1-5064
4	17.70	17.80	2983	1-3352	13.34	13 60	1-2994	1-2700	.....
5	18.20	18 50	3080	1-3246	13 33	13 80	1 2098	1-2718	1-3610
6	19.70	19.90	3304	1-3026	13.80	14.50	1-2913	1-2728	1-3601
7	18.10	18.75	3192	1-3132	13 30	13.40	1-3040	1-2895	1-3590
8	17 00	18.00	2941	1-3279	13.40	13.40	1 3089	1-2878	1-3630
9	18.20	18 00	3103	1-3222	13.52	13 35	1-3049	1-2796	1-3528
10	17.80	31.03	3108	1-3113	13.60	13.70	1-2903	1-2656	1-3522
11	18.35	18.70	3172	1 3152	14 00	13 80	1-2882	1 2793	1-3520
12	18.65	18.75	3013	1-3319	13.70	13.80	1-2945	1-2816	1 3675
13	18.45	19 20	3233	1 3093	13.80	14.20	1-2992	1-2700	1-3678
14	17.00	17.30	2981	1-3354	13.05	13.15	1-3092	1-2890	1-3681
15	19.00	18.80	3096	1-3229	14.00	14.25	1-2919	1-2790	1-3241
16	18.85	19.10	3254	1 3073	13.60	13.60	1-2989	1-2755	1 3370
17	17.10	17 28	2390	1-3456	14.09	14 10	1-2874	1-2847	1-3376
18	17.35	18.20	3043	1-3281	12 80	13.40	1-3092	1-2895	1 3986
19	18.85	19.15	3254	1 3073	13 60	14.00	1-2882	1-2748	1-3986
20	17.10	17.30	2945	1-3382	12.90	13.30	1-3092	1-2945	1-3995
21	18.10	18.15	3107	1 3218	13.60	13.90	1 2545	1-2850	1-4001
22	17.90	18.10	3080	1 3246	13.45	13.90	1-2962	1 2893	1 3995
23	17.40	17.90	3025	1 3305	18.20	13.70	1-3038	1 2710	1-3930
24	17.90	17.40	3025	1 3305	13.20	13.40	1-3046	1-2893	1 3940
25	18.00	18.25	3106	1-3219	12.90	13.40	1-3080	1 2955	1-3935
26	18.00	18.30	3109	1 3214	13.30	13.20	1-3057	1 2893	1-3990
27	17.90	18.20	3095	1 3231	13.30	13.65	1 3005	1-2755	1-3941
28	17.70	17 90	3015	1 3314	13 10	13.40	1-3095	1-2877	1-3948
29	17.30	17.10	2969	1 3367	13.80	13.30	1 3038	1-2982	1-3980
30	17.10	17 20	3022	1-3309	13.00	13 20	1-3091	1-2793	1-3840
31	17.95	18.55	3133	1 3201	13.60	13.70	1 2967	1-2788	1-3760
32	19.30	18.80	3266	1-3061	13.80	13.90	1 2924	1 2790	1 3167
33	18 30	18.35	3141	1-3183	13.35	13.60	1-2994	1 2656	1-3770
34	18.20	18.50	3146	1-3178	13.80	13.90	1-2724	1-2735	1-4315
35	17.20	17 15	2970	1-3295	13.15	13.15	1-3080	1 3161	1-3578
36	17.60	17.10	2968	1-3368	13.40	13.90	1-2964	1 2825	1 4260
37	18.10	18.10	3114	1-3211	13.35	13.31	1-3090	1-2735	1 4270
38	17.15	17.20	2969	1-3367	15.00	15 00	1-2700	1 2504	1 5765
39	18.30	19.00	3201	1-3124	13.60	14.00	1-2935	1-2842	1 3862
40	17.90	17.50	3034	1-3295	13.25	13.45	1-3033	1 2934	1-3854
41	16 70	18 20	3025	1 3305	13.50	13.80	1 2935	1-2890	1-3860
42	17.50	17.65	3000	1-3333	12.80	12.90	1-3155	1-2893	1 3850
43	17.70	18.15	3088	1-3238	13.15	13.20	1-3068	1-2842	1 3855
44	18.00	18 45	3123	1 3201	13 30	13.68	1-3005	1-2840	1-3848
45	19.20	19.20	3291	1 3038	13.25	13.50	1-3029	1 2710	1-3240
46	16.10	16.60	2600	1-3568	12.30	12.60	1-3253	1 2945	.....
47	17.10	17.17	2880	1-3467	12.40	12.50	1-3253	1 2700	1-3628
48	18.75	19.25	3257	1-3070	13.75	14 25	1-2890	1-2705	1-3681
49	18.85	18.35	3223	1 3097	.....	.....	.....	1 2948	.....
50	.....	.....	3009	1 3323	.....	.....	.....	.....	.....

First Infant 2 Weeks, Second 1 Day, Third 2 Days Old.

1	20.40	20.30	3497	1-2854	.....	.....	1-2604	1-2531	1 4545
2	20.45	20.55	3508	1-2847	.....	.....	1 2621	1-2530	1-5400
3	20.20	19.60	3411	1-2931	.....	.....	1-2538	1-2538	1-4560

Synopsis (No. 2). Dog's blood.

The forms of the blood corpuscles, the measurement of which is summed up in this synopsis, were arranged in tables precisely as described in the synopsis of human blood measurement.

Synopsis (No. 2) of measurement of dogs' blood corpuscles magnified 1620 diameters.

Number.	Measure in inches of 50 dogs' blood tables of 36 corpuscles each—measured in two directions.		Average in ten millionths of an inch.	Average in vulgar fractions.	Measure in inches of 50 tables of largest selected corpuscles, 25 each, measured in two directions.		Average of large selected corpuscles.	Measurement of largest corpuscles.	Smallest corpuscles.
1	16.60	17.30	2855	1-3502	12.60	12.60	1-3333	1-3016	1-3926
2	16.10	15.90	2737	1-3649	12.10	12.60	1-3273	1-3237	1 4375
3	16.60	16.65	2848	1-3512	13.30	12.60	1-3259	1-3113	1-3846
4	17.11	17 50	2969	1 3361	12 80	12.90	1 3152	1-3010	1-3764
5	17.00	17.55	2962	1-3375	12 90	12.95	1-3112	1-3000	1-4000
6	17.10	17.45	2976	1 3382	12.60	13.10	1 3092	1-2990	1 4112
7	17.11	16.75	2907	1 3439	12 55	12.25	1 3273	1-3113	1-4114
8	16 00	16.60	2766	1 3628	12 30	12.70	1 3280	1-3170	1-4020
9	17.15	17.75	2950	1 3403	12.30	12.80	1-3228	1-3178	1 3767
10	16.50	14.90	2695	1-3710	12 30	12.70	1 3230	1 3177	1-4010
11	17.05	17.15	2932	1-3410	13 35	13.05	1-3068	1 2961	1-3936
12	17.11	16.80	2888	1 3456	12.90	13.65	1 3051	1-2964	1-3846
13	16.60	16.90	2877	1-3475	12.60	12.85	1 3222	1 2987	1 4375
14	17.65	15.35	2827	1 3533	13 70	13.10	1-3092	1-2929	1-3846
15	16.10	16.14	2886	1 3465	12.30	12.30	1-3225	1-3178	1-3600
16	16.90	17 30	2962	1 3375	12.60	12.80	1-3253	1-3115	1 4391
17	15.90	16.40	2764	1 3616	12 20	12 20	1 3320	1-3113	1 4262
18	16.40	16.61	2826	1 3538	12 30	12.80	1-3225	1 3065	1-4000
19	15 89	15.80	2713	1 3685	12.38	12.89	1-3134	1 2922	1-4206
20	16.44	16 65	2826	1-3538	11.58	11.66	1-3483	1 3223	1-3870
21	12.66	13.30	2213	1-4166	11 18	11.24	1 3605	1-3244	1-5227
22	18.00	16.40	2911	1 3390	13.30	13 50	1 3022	1-2893	1 3767
23	17 30	17.50	2962	1-3376	12.80	12 90	1-3192	1-2899	1-4154
24	17.20	17.85	2962	1-3375	13 50	13 10	1 3083	1 2883	1-4875
25	17.50	16.60	2917	1-3428	12.30	12.70	1-3309	1-2939	1-4055
26	13.40	15.58	2964	1-3373	12.88	12.86	1-3133	1-2951	1-4000
27	16.90	17.30	2931	1-3411	12.30	12.70	1 3309	1-3214	1-4010
28	17.15	17.40	2962	1-3976	12.65	12.90	1-3170	1 3009	1 4010
29	17 00	17.40	2956	1 3403	12.60	12.90	1 3240	1-2759	1 3850
30	17.14	17.40	2962	1-3075	12.65	12.90	1-3170	1 3009	1-3364
31	17.00	16 60	2876	1-3447	13 40	13 80	1-3019	1 2949	1 4629
32	16.20	16 65	2707	1 3657	12.45	12 65	1 3202	1 2934	1 4996
33	18.70	17.90	2981	1 3351	12.50	12.85	1 3257	1-2892	1 5227
34	15.50	18 70	2679	1 3732	13.10	13 10	1-3093	1-2837	1-4766
35	16 45	16.95	2858	1-3498	13.10	13.40	1-3236	1-2817	1-5328
36	16.50	16.20	2768	1-3612	13.40	13.60	1 3068	1-2828	1-4970
37	17.00	17.00	2913	1-3432	13 20	12.90	1-3100	1-2844	1-5106

Puppies' Blood.

38	17.30	17.90	3017	1-3314	12.30	12.60	1-3253	1-3022	1-3764
39	18.00	17.70	3063	1-3264	13.20	12.90	1-3103	1-3020	1-3354
40	18.10	18 10	3087	1-3239	13.35	13.45	1-3022	1-3000	1-3360
41	17 60	18.20	3069	1-3275	13.20	13.60	1-3022	1-2857	1-3846
42	17.10	17.20	2938	1-3414	12 80	12.60	1-3253	1-3163	1-4150
43	17.30	17.80	3001	1-3324	12.90	14.10	1-3000	1-2936	1-3447
44	17.60	18.00	3081	1-3274	13.80	12.80	1-3033	1-2829	1-4370
45	17.70	18.15	3072	1-3255	13.25	13.60	1-3017	1-2847	1-4975
46	17.50	18.00	3043	1-3286	12.48	13.00	1-3150	1 2755	1-3846
47	17.70	18.15	3069	1-3258	13.25	13.60	1-3017	1-2847	1-4275
48	19.10	17.50	3137	1-3187	14.70	13.80	1-2842	1-2549	1-4663
49	18.45	17.70	3098	1-3227	13.75	13.68	1-3068	1-3026	1-3846
50	17.70	17.50	3015	1-3316	13.10	13.80	1-3041	1-2944	1-3846

The average of adult dogs and puppies together is in ten-millionths of an inch, and vulgar fractions: 2946 = 1–3394 of an inch; average of adult alone. 2854 = 1–3502 of an inch; average of puppies alone, 3050 = 1–3285 of an inch.

The number thirty-six (36) corpuscles in the tables is not given as being considered sufficient to settle the precise average in a given case, but as being convenient for the purpose of illustrating certain other comparisons instituted in my paper. It will be noticed, however, how close the averages in these comparatively meagre tables come to those made from those much more extended ones on which my former published averages were based. The difference between the dog blood averages, as obtained from these tables, and from the others as above, amounts to the 18 ten-millionths of an inch, and between the human blood averages to the 17-ten-millionths of an inch.

Synopsis (No. 3) of 24 tables of 48 corpuscles each; from the blood of one individual

Tables of 48 corpuscles, same individual.	1	0002949	1–3390 of an inch.
	2	0002952	1–3387 " "
	3	0002921	1–3423 " "
	4	0002970	1–3467 " "
	5	0002944	1–3390 " "
No. 7 = 1–3305 of an inch.	6	0002910	1–3435 " "
8 = 1–3344 " "	7	0002970	1–3367 " "
9 = 1–3320 " "	8	0002934	1–3370 " "
10 = 1–3331 " "	9	0002949	1–3390 " "
	10	0002956	1–3382 " "
	11	0002958	1–3414 " "
	12	0002921	1–3418 " "
	13	0002952	1–3387 " "
	14	0002949	1–3390 " "
Tables of another individual, 49 corpuscles each	15	0002959	1–3379 " "
	16	0002959	1–3379 " "
	17	0002921	1–3418 " "
	18	0002923	1–3421 " "
No. 1 = 1–3488 of an inch.	19	0002956	1–3382 " "
2 = 1–3503 " "	20	0002963	1–3374 " "
3 = 1–3491 " "	21	0002934	1–3370 " "
4 = 1–3530 " "	22	0002934	1–3370 " "
	23	0002950	1–3389 " "
	24	0002913	1–3425 " "